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NAVWEPS REPORT 7933
NOTS TP 2965
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NEAR-INFRARED REFLECTANCES OF NAVAL AIRCRAFT SURFACES AND COATINGS

(U)

by

Frederick J. Koperski
Aviation Ordnance Department

ABSTRACT. This report describes a measurement program to obtain information on the near-infrared reflectance of surfaces and coatings commonly used in modern high-speed naval aircraft. Measurements were restricted to normal incidence and near-normal reflection, the 0.7-micron (μ) to 1.2-μ band, and illumination by xenon discharges. Miscellaneous surfaces such as desert soil and concrete buildings were also examined. (UNCLASSIFIED)

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U.S. NAVAL ORDNANCE TEST STATION

China Lake, California

July 1962

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U. S. NAVAL ORDNANCE TEST STATION

AN ACTIVITY OF THE BUREAU OF NAVAL WEAPONS

C. BLENMAN, JR., CAPT., USN
Commander

WM. B. MCLEAN, PH.D.
Technical Director

FOREWORD

The measurement program described in this report was made early in 1962 at the U. S. Naval Ordnance Test Station (NOTS) to obtain general information on infrared reflectances of naval aircraft. The work was accomplished under Foundational Research WepTask R360-FR 106/216-1/R011-01-001.

The report has been reviewed for technical accuracy by J. Lamar and H. P. Leet.

Released by
N. E. WARD, Head
Aviation Ordnance Department
10 July 1962

Under the authority of
Wm. B. McLEAN
Technical Director

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INTRODUCTION

The need frequently arises for knowing the near-infrared reflectances of surfaces and coatings of modern high-speed naval aircraft. To obtain this information, this Station has made both laboratory and field measurements of particular directional reflectances of various aircraft surfaces and coatings, using a xenon discharge source and a suitable infrared-sensitive detector. In the measurement program, some miscellaneous materials were also examined.

TECHNIQUES AND PROCEDURES

INSTRUMENTATION

The technique for laboratory measurements was substitutional. Incident light from the xenon discharge illuminated a "standard" material, and the level of the reflected flux was measured by the detector and recorded on an oscilloscope. The standard material was then replaced by the material under consideration, and the reflected flux was measured again. The ratio of these two measurements was defined as the directional reflectance[1] for the particular geometry used.

The reflectances reported here are not defined in the usual sense. Reflectances in general are wavelength dependent, but no attempt was made here at wavelength resolution. The primary interest was an integrated reflectance for the 0.7-micron (μ) to 1.2-μ band. The spectral quality of the incident flux and the detector's responsivity further restricted the interpretation of these reflectances. The reflectances reported are therefore specifically for the source—detector combination being used.

Figure 1 is a schematic of the instrumentation. The light source used for incident illumination was the xenon discharge lamp contained in the General Radio Strobotac Type 1531-A. This provided an adequate pulsed source of 0.7-μ to 1.2-μ band light. The pulse duration was 4 μsec with a

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[1] $\text{Directional reflectance} = \dfrac{\text{Reflected flux from sample}}{\text{Reflected flux from standard}}$

repetition rate of 400 pulses per second. After collimation, the source flux was reflected from a 45-degree mirror onto the material under consideration. The incidence was normal. The intensity of the reflected flux was measured by sighting through the 45-degree mirror with a silicon photodiode, RCA Type C-3-25-2.0. The output was registered on a Tektronix Type 317 oscilloscope. The detector's input aperture was limited to receive only the flux reflected from the specimen. Figure 2 shows the relative spectral response of the photodiode and xenon discharge combination. With this arrangement, the directional reflectance measured was that for normal incidence and near-normal reflection. In order to measure reflectances for normal incidence and 35-degree-off-normal reflection, an alternate arrangement, shown in Fig. 3, was used.

SAMPLE PREPARATION

Laboratory samples were prepared by painting 2-inch squares of aluminum plate with the same paints used on naval aircraft. For comparison, a good diffusely reflecting surface was prepared by chemically etching one of the aluminum plates.

REFLECTANCE STANDARDS

A primary standard was prepared by coating an aluminum plate with magnesium oxide (MgO) produced by burning magnesium tape. The absolute diffuse reflectance of MgO is well known[2] and is approximately 0.96 for the 0.7-μ to 1.2-μ region.[3] Because of its physical fragility, the MgO surface was not used throughout the reflectance measurements. Instead, a secondary standard was calibrated in terms of the MgO. This secondary standard was pebbled matt board, a flat-white diffusely reflecting surface. The ratio of reflectance of the secondary to the primary standard was 0.957.

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[2] Sanders, C. L., and W. E. Middleton. "The Absolute Spectral Diffuse Reflectance of Magnesium Oxide in the Near Infrared," J OP SOC AMER, Vol. 42 (November 1952), p. 881.

[3] Diffuse reflectance is reflectance into 2π steradians obeying the cosine law of intensity distribution. It is quantitatively defined as total reflected flux / total incident flux.

FIELD MEASUREMENTS

For comparison with laboratory results, reflectance measurements of surfaces and coatings of aircraft were made. The instrumentation was modified in order to illuminate larger surface areas. A 3- by 3-foot area was measured. The same white matt secondary standard was used; the technique again was substitutional. Although some of the areas measured on the aircraft were convex relative to the illumination direction, the reflectances were always compared with the plane standard. No attempt was made to make the surface of the secondary standard convex. The separation distance was 3 feet throughout the measurements.

DATA DISCUSSION AND PRESENTATION

Results of the laboratory measurements are compiled in Table 1. Color designations are those of paints currently used in the Fleet. Control surfaces of modern naval aircraft are usually painted Insignia White or a bright red-orange called Da-Glo. The fuselage of the F4H is a white-gray called Gull Gray. Seaplane Gray is the dark gray frequently found on Navy helicopters.

TABLE 1. Laboratory Measurements of Directional Reflectance (Footnote 1)

Surface	Normal incidence, near-normal reflection	Normal incidence, 35-deg-off-normal reflection
Navy Gray	0.95	0.22
Insignia White	2.25	1.00
Da-Glo	0.90	0.83
Da-Glo + Clear Coat	1.35	0.83
Flat black	0.28	0.27
Gull Gray	0.60	0.39
Seaplane Gray	0.60	0.16
Zinc chromate	0.60	0.50

Some of the above coatings were also measured on aircraft parked in a hangar (Table 2). None of the aircraft surfaces were both flat and clean. They were usually oil—dirt streaked, and dimpled convex. The illumination direction and the "look" direction of the receiver were essentially coincident.

TABLE 2. Field Measurements of Directional Reflectance

Surface	Normal incidence, near-normal reflection
Insignia White	0.87
Da-Glo	0.85
Gull Gray	0.35
Seaplane Gray	0.40

For general information, reflectances at normal incidence and near-normal reflection were also measured from the miscellaneous surfaces shown in Table 3.

TABLE 3. Measurements of Directional Reflectance

Surface	Normal incidence, near-normal reflection
Desert sand of average grit and tan color	0.50
Chemically etched aluminum plate	1.62
B-29 elevator surface, heavily dimpled, desert-weathered	3.67
Exterior concrete wall of Michelson Laboratory	0.50

The occurrence of directional reflectances greater than 1.0 in the collected data was not unusual, for some of the samples were very specular as compared with the standard material, which was a diffuse reflector. Although the diffuse reflectance of MgO is nearly 1.0 (footnote 2), this is a measure of the flux reflected into 2π steradians. The associated normal reflectance of MgO for small solid angles is proportionately smaller. Therefore, samples having a high normal specularity would give directional reflectances greater than 1.0 when compared with diffusely reflecting materials. When comparing perfectly specular reflection with perfectly diffuse reflection from the same material, the maximum directional reflectance we could expect is 2π. This can be seen from the following:

$$F_{diffuse} = \rho F_0 \, (1/2\pi) \cos\theta$$

$$F_{specular} = \rho F_0,$$

where

$F_{diffuse}$ = flux reflected in the diffuse situation

$F_{specular}$ = flux reflected in the specular situation

F_0 = incident flux

θ = angle between the reflected ray and the normal to the reflecting surface

ρ = reflection coefficient.

Then for normal reflection,

$$\frac{F_{specular}}{F_{diffuse}} = 2\pi.$$

CONCLUSIONS

On the basis of the measurements of this study one can assume, for calculations involving analogous instrumentation, that for normal incidence and near-normal reflection, most naval aircraft surfaces have a minimum normal reflectance of 0.3.

The measured reflectance obtained for desert sand is compatible with that measured by Coulson.[4]

[4] Coulson, K. L., "Characteristics of Solar Radiation Reflected from Desert Soil," Dept. of Meteorology, U.C.L.A., September 1956.

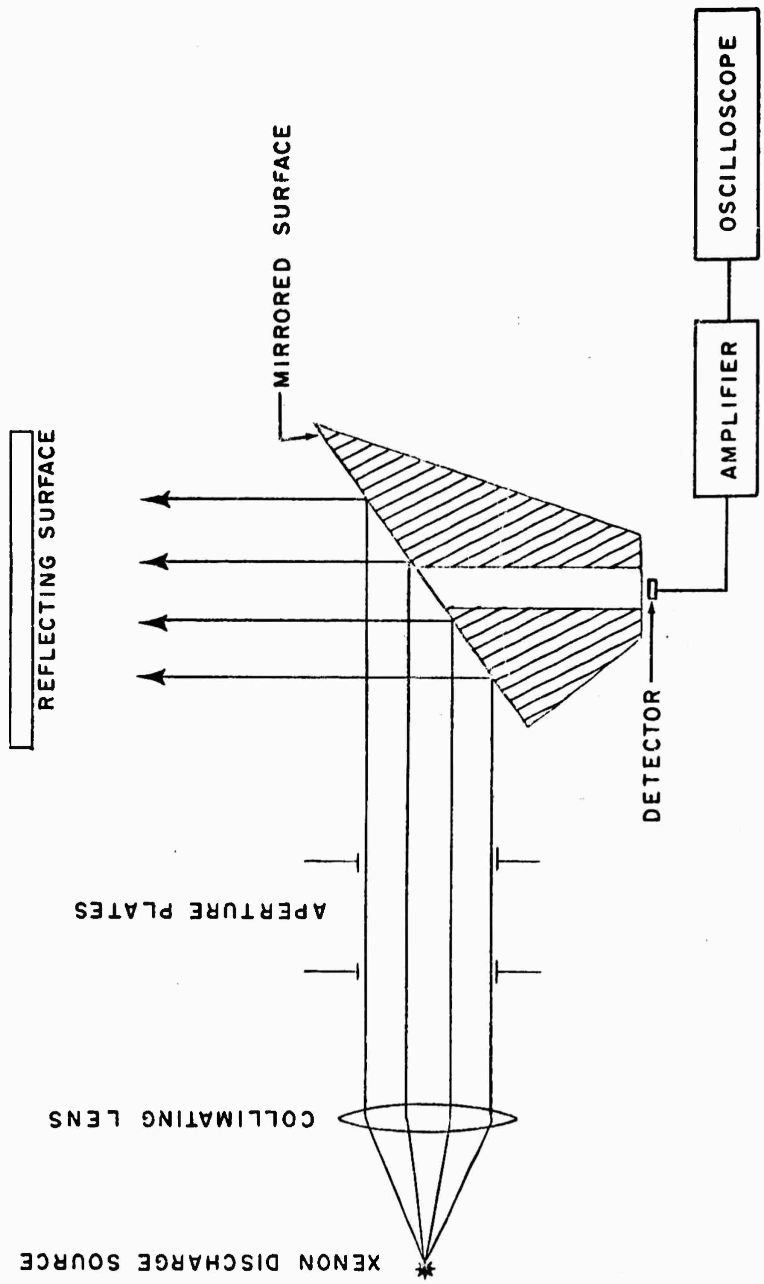

FIG. 1. Reflectometer Instrumentation.

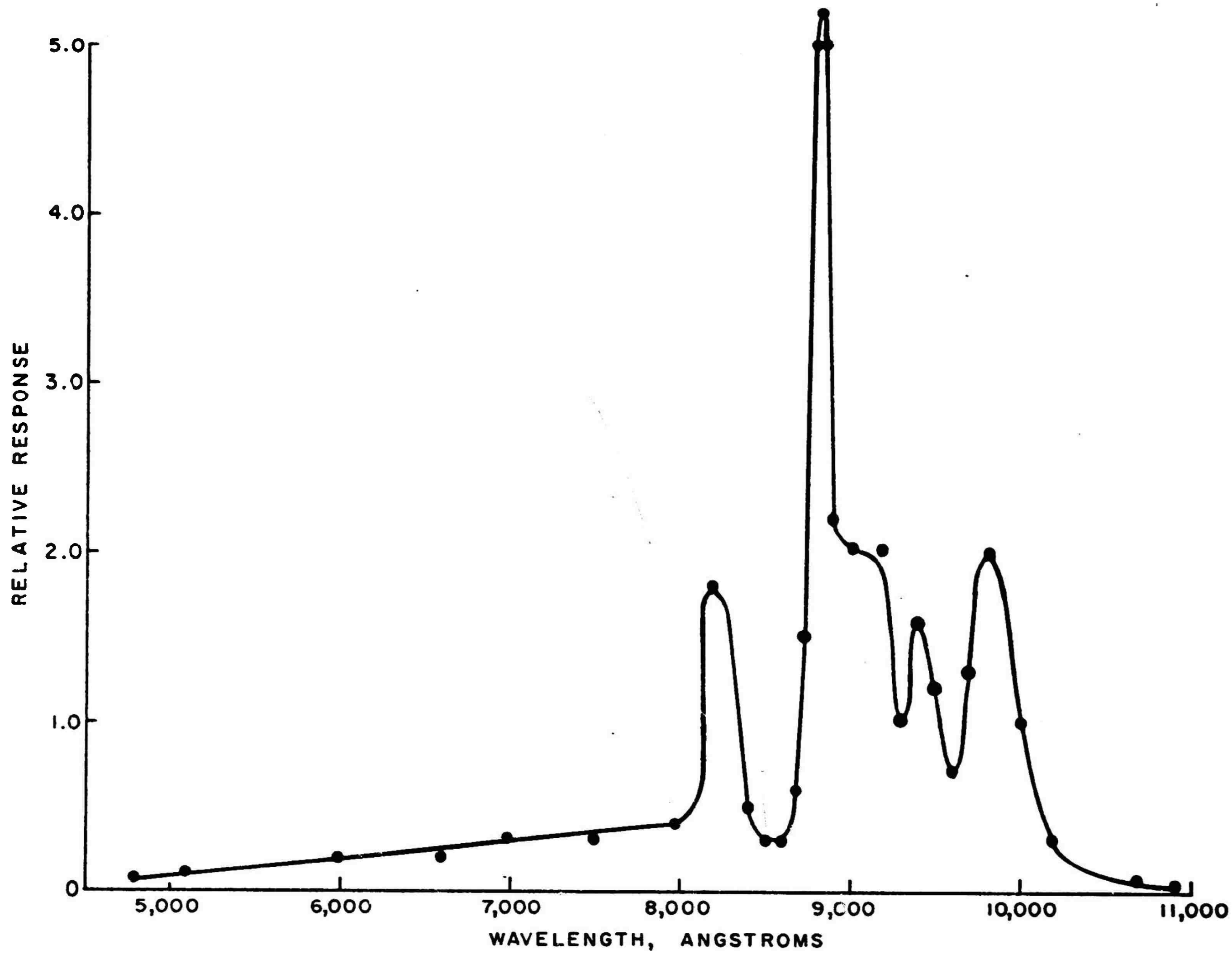

FIG. 2. Response Characteristics of Xenon Discharge—Silicon Diode Detector Combination. 3-kc flashing rate, 0.1-mm geometrical slit width.

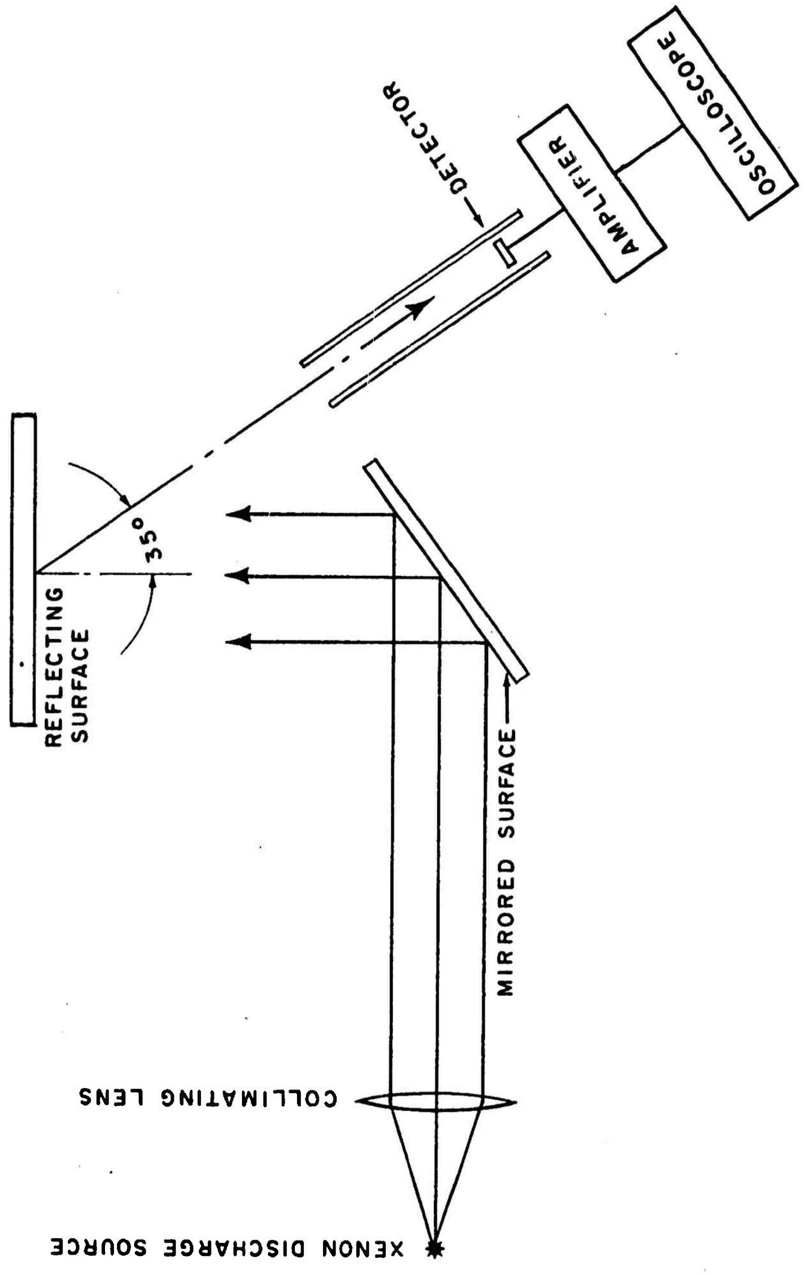

FIG. 3. Alternate Reflectometer Instrumentation.

ABSTRACT CARD

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